

Technical Report  
1073

**GBS IOTE Feed Measurements**

T.W. Borge

23 May 2001

---

**Lincoln Laboratory**  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
LEXINGTON, MASSACHUSETTS



Prepared for the Air Force under Contract F19628-00-C-0002.

Approved for public release; distribution is unlimited.

20010620 141

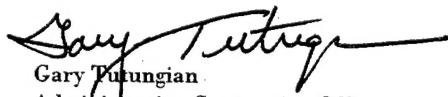
This report is based on studies performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology. This work was sponsored by the Air Force, SMC/MCW, under Contract F19628-00-C-0002.

This report may be reproduced to satisfy needs of U.S. Government agencies.

The ESC Public Affairs Office has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

**FOR THE COMMANDER**



Gary Tufungian  
Administrative Contracting Officer  
Plans and Programs Directorate  
Contracted Support Management

Non-Lincoln Recipients

PLEASE DO NOT RETURN

Permission has been granted by the Contracting Officer to destroy this document, when it is no longer required by the using agency, according to applicable security regulations.

Massachusetts Institute of Technology  
Lincoln Laboratory

## **GBS IOTE Feed Measurements**

*T.W. Borge  
Group 63*

**TECHNICAL REPORT 1073**

**23 May 2001**

**Approved for public release; distribution is unlimited.**

Lexington

Massachusetts

## **ABSTRACT**

The Ka-Band (30/20 GHz) terminal was used to conduct I, O, T, and E of the Global Broadcast System (GBS) package on UHF Follow-on (UFO) satellites, flights 8, 9, and 10. This terminal has been transferred to Lincoln Laboratory through the Milsatcom Joint Program Office at the USAF Space and Missile Center (AFSMC). At Lincoln Laboratory, the terminal is to be evaluated for possible use in on-orbit checkout/experimentation with the Ka-band portion of the Wideband Gap Filler Satellites (expected to launch in 2004). These satellites use the government 20.2–21.2 GHz (downlink) and 30–31 GHz (uplink) frequency allocations. This report describes the test and evaluation of the Ka-Band Terminal dual frequency feed at Lincoln Laboratory's Antenna Test Range and identifies some deficiencies that will need to be addressed prior to use with the Wideband Gapfiller system.

## **TABLE OF CONTENTS**

|                         | <b>Page</b> |
|-------------------------|-------------|
| Abstract                | iii         |
| 1.0 INTRODUCTION        | 1           |
| 2.0 MEASUREMENT SYSTEM  | 3           |
| 3.0 MEASUREMENT RESULTS | 5           |
| 4.0 CONCLUSION          | 19          |

## LIST OF ILLUSTRATIONS

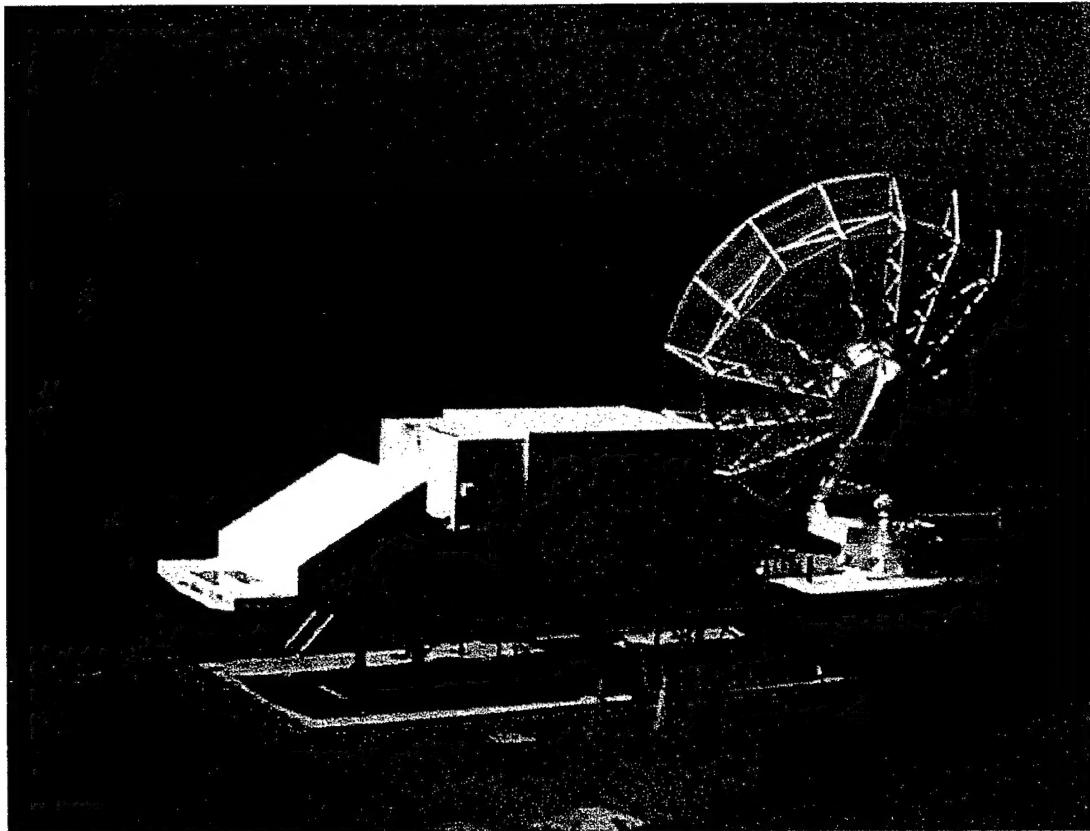
| <b>Figure</b> |   | <b>Page</b> |
|---------------|---|-------------|
| 1             | GBS-IOTE Ka-Band Terminal.  | 1           |
| 2             | GBS-IOTE Antenna Feed in anechoic chamber.                                  | 3           |
| 3             | Ka-Band Return Loss graph.  | 6           |
| 4             | Ka-Band VSWR graph.   | 6           |
| 5             | Ka-band RHCP Swept Frequency gain graph.                                    | 7           |
| 6             | Ka-Band axial ratio graph.  | 7           |
| 7             | 29 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern.    | 8           |
| 8             | 29.25 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern. | 8           |
| 9             | 29.5 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern.  | 9           |
| 10            | 29.75 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern. | 9           |
| 11            | 30 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern.    | 10          |
| 12            | 30.25 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern. | 10          |
| 13            | 30.5 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern.  | 11          |
| 14            | 30.75 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern. | 11          |
| 15            | 31 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) azimuth radiation pattern.    | 12          |
| 16            | K-Band Return Loss graph.   | 14          |
| 17            | K-Band VSWR graph.  | 14          |
| 18            | K-band LHCP Swept Frequency gain graph.                                     | 15          |
| 19            | K-Band swept frequency on axis axial ratio graph.                           | 15          |
| 20            | 20.2 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) azimuth radiation pattern.  | 16          |
| 21            | 20.45 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) azimuth radiation pattern. | 16          |
| 22            | 20.70 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) azimuth radiation pattern. | 17          |
| 23            | 20.95 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) azimuth radiation pattern. | 17          |
| 24            | 21.2 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) azimuth radiation pattern.  | 18          |

## LIST OF TABLES

| <b>Table</b>   | <b>Page</b> |
|--|-------------|
| 1. Ka-band (29-31 GHz) tabular data (axial ratio, gain, return loss, VSWR, beam width and cross-polar).    | 5           |
| 2. K-Band (20.2-21.2 GHz) tabular data (axial ratio, gain, return loss, VSWR, beam width and cross-polar). | 13          |

## 1.0 INTRODUCTION

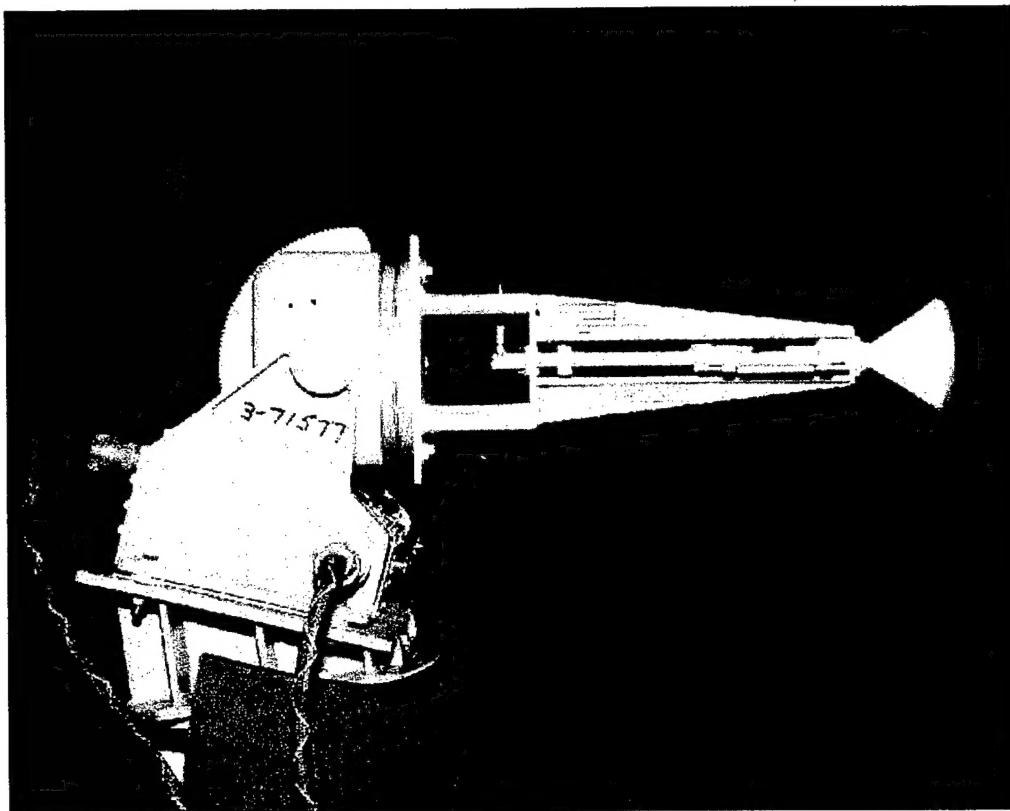
The Ka-band dual frequency feed (Figure 1) was tested and evaluated at the MIT Lincoln Laboratory Antenna Test Range. Originally specified to operate from 20.25–20.75 GHz (downlink) and 30–30.5 GHz (uplink), measurements were made from 20.2–21.2 GHz and 29–31 GHz in an attempt to determine if the feed could operate in the 20.2–21.2 GHz and the 30–31 GHz Wideband Gapfiller bands.



*Figure 1. GBS-IOTE Ka-Band Terminal*

## 2.0 MEASUREMENT SYSTEM

Measurements were performed in anechoic chamber #2 using the Hewlett Packard 8530 receiver and the Antenna Measurement Program (AMP) software developed by Dave Besse of Lincoln Laboratory. Return loss measurements were conducted on the Hewlett Packard 8510C network analyzer at both frequency bands. Figure 2 shows the GBS IOTE feed on an elevation /azimuth positioner in the anechoic chamber.



*Figure 2. GBS-IOTE Antenna Feed in Anechoic Chamber*

### 3.0 MEASUREMENT RESULTS

Azimuth radiation patterns from -90 to 90 degrees, swept frequency gain, and axial ratio measurements were performed. Table 1 shows the Ka-Band (transmit) axial ratio, gain, return loss, VSWR, beam widths and cross-polar data for frequencies in the 29–31 GHz range. Data results indicate that performance of the feed rapidly deteriorates in both axial ratio and gain above 30.6 GHz. For a 1 GHz bandwidth between 29.6–30.6 GHz, data results demonstrate a <2.1 db axial ratio, nominal gain of 15.1 dbi, return loss <13.3 db, and a 1.55 maximum VSWR. Figures 3 and 4 depict the Ka-Band return loss and the corresponding VSWR graphs. Figures 5 and 6 show the Ka-Band swept gain (for RHCP) and axial ratio plots. The Ka-Band co-polar (RHCP) and cross-polar (LHCP) azimuth patterns are indicated in Figures 7–15, note the asymmetry in the patterns at 30.75 and 31 GHz figures (Figure 14 and 15). Table 2 lists the K-Band (Receive) axial ratio, gain, return loss, VSWR, beam widths, and cross-polar data for frequencies between 20.2-21.2 GHz. Data results indicate <1.7 db axial ratios, nominal gain of 15.5 dbi, return loss <16.6 db, and a maximum VSWR of 1.35. Also presented are the beam widths and cross-polar data. Figures 16 and 17 represent the Ka-band return loss and the corresponding VSWR graphs. The K-Band swept gain (for LHCP) and axial ratio plots are shown in Figures 18 and 19. Figures 20–24 depict the K-band co-polar (LHCP) and cross-polar (RHCP) azimuth radiation patterns.

**Table 1. Ka-Band Antenna Feed Tabular Data**

| Freq (GHz) | Axial Ratio (dB)             | Gain (dbi)                    | Return Loss (dB) | VSWR |
|------------|------------------------------|-------------------------------|------------------|------|
| 29.00      | 3.05                         | 15.41                         | -17.63           | 1.30 |
| 29.10      | 2.83                         | 15.53                         | -24.66           | 1.12 |
| 29.20      | 2.80                         | 14.92                         | -17.33           | 1.31 |
| 29.30      | 2.62                         | 15.40                         | -16.19           | 1.37 |
| 29.40      | 2.55                         | 15.64                         | -30.78           | 1.06 |
| 29.50      | 2.30                         | 15.16                         | -14.00           | 1.50 |
| 29.60      | 2.10                         | 15.10                         | -17.66           | 1.30 |
| 29.70      | 1.85                         | 14.64                         | -18.73           | 1.26 |
| 29.80      | 1.80                         | 14.93                         | -13.29           | 1.55 |
| 29.90      | 1.53                         | 15.27                         | -24.93           | 1.12 |
| 30.00      | 1.30                         | 14.85                         | -15.14           | 1.42 |
| 30.10      | 1.15                         | 15.36                         | -18.33           | 1.28 |
| 30.20      | 0.76                         | 15.48                         | -20.95           | 1.20 |
| 30.30      | 0.81                         | 15.52                         | -16.62           | 1.35 |
| 30.40      | 0.89                         | 15.56                         | -22.44           | 1.16 |
| 30.50      | 1.27                         | 15.15                         | -16.83           | 1.34 |
| 30.60      | 1.90                         | 14.72                         | -16.38           | 1.36 |
| 30.70      | 2.85                         | 14.45                         | -16.56           | 1.35 |
| 30.80      | 3.95                         | 13.70                         | -21.97           | 1.17 |
| 30.90      | 4.60                         | 13.33                         | -11.03           | 1.78 |
| 31.00      | 6.55                         | 12.42                         | -14.61           | 1.46 |
| Freq (GHz) | BeamWidth (3dB) <sup>o</sup> | BeamWidth (10dB) <sup>o</sup> | X-pol (dB)       |      |
| 29.00      | 32.09                        | 51.27                         | -14.77           |      |
| 29.25      | 33.02                        | 53.23                         | -18.37           |      |
| 29.50      | 33.70                        | 53.77                         | -15.75           |      |
| 29.75      | 33.62                        | 53.26                         | -14.58           |      |
| 30.00      | 34.16                        | 53.41                         | -15.51           |      |
| 30.25      | 34.05                        | 53.23                         | -15.09           |      |
| 30.50      | 34.43                        | 54.16                         | -13.29           |      |
| 30.75      | 35.57                        | 55.77                         | -9.48            |      |
| 31.00      | 33.20                        | 53.80                         | -3.96            |      |

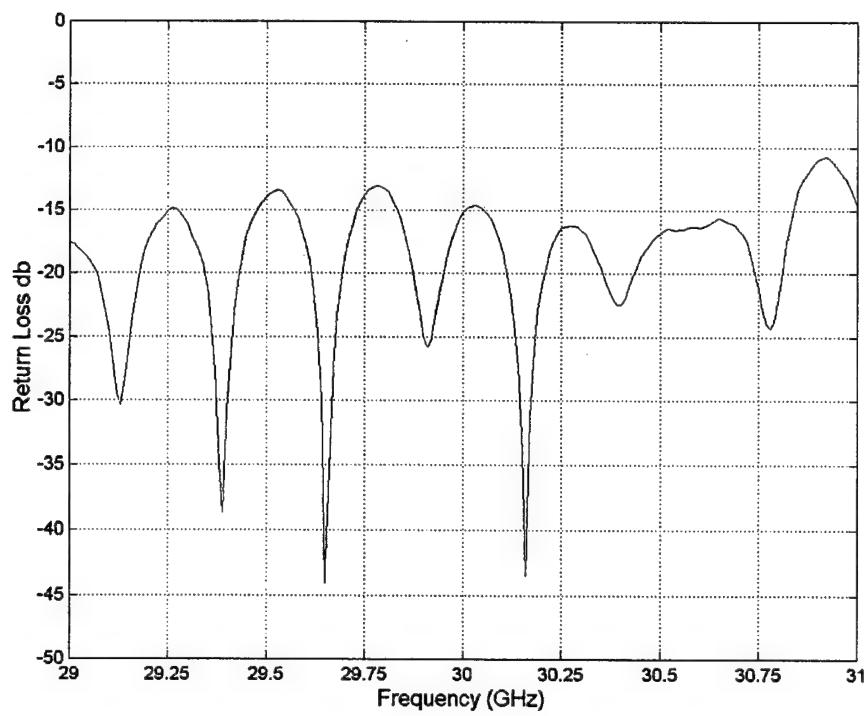


Figure 3. Ka-Band Return Loss Graph

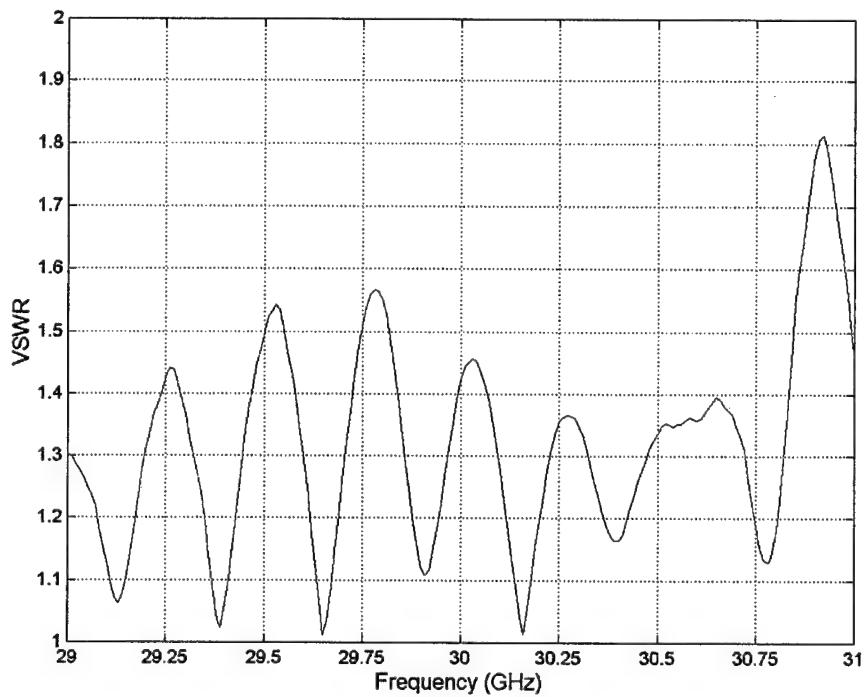


Figure 4. Ka-Band VSWR Graph

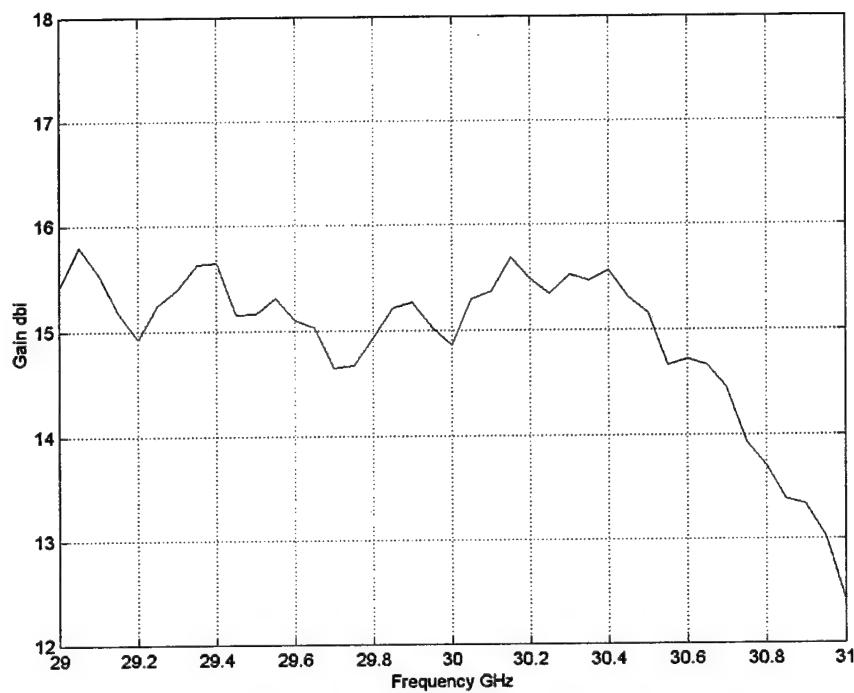


Figure 5. Ka-Band RHCP Swept Frequency Gain Graph

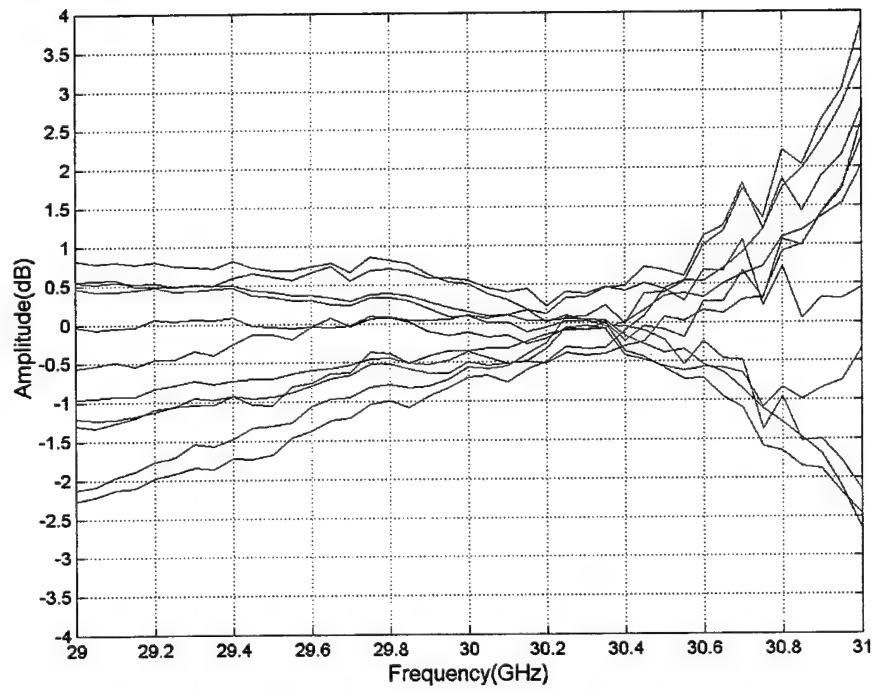


Figure 6. Ka-Band Axial Ratio Graph

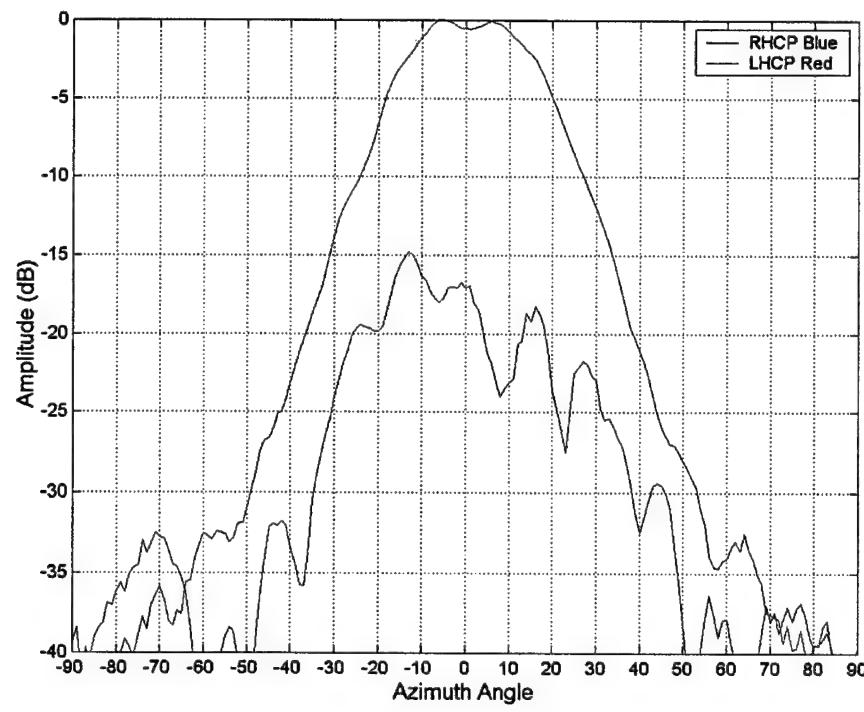


Figure 7. 29 GHz Co-Polar (RHCP) and Cross Polar (LHCP) Azimuth Radiation Pattern

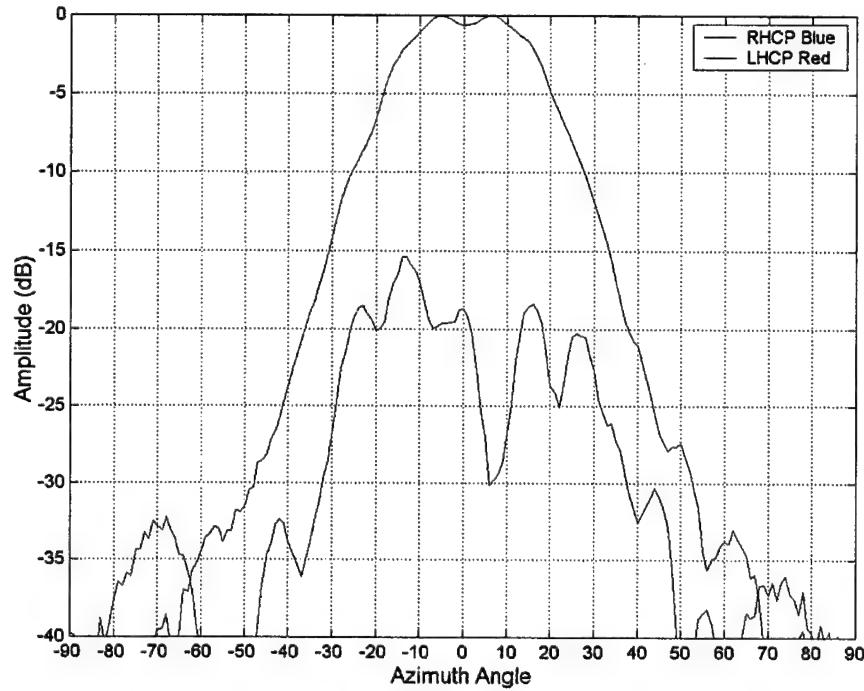
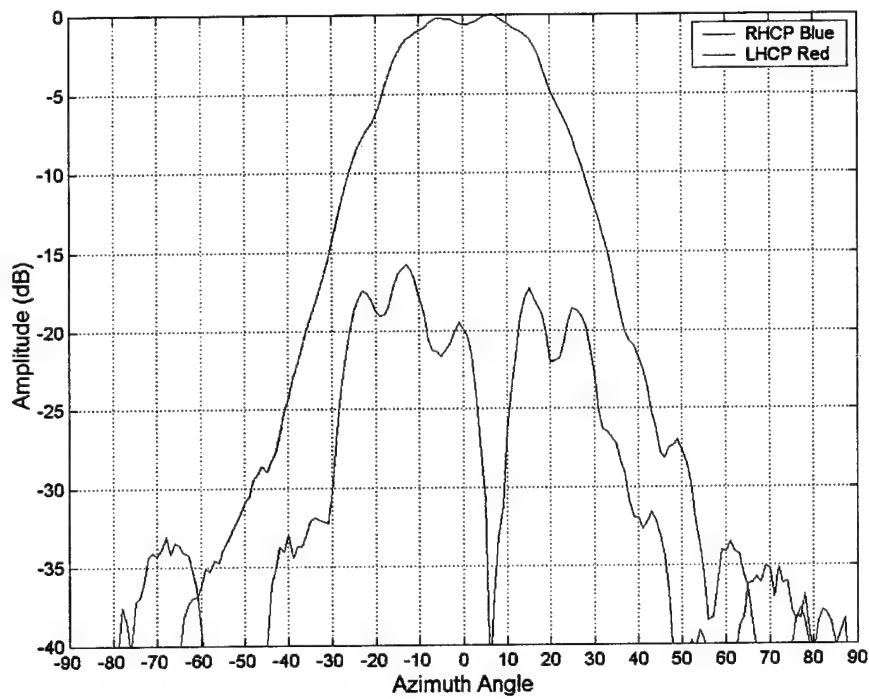
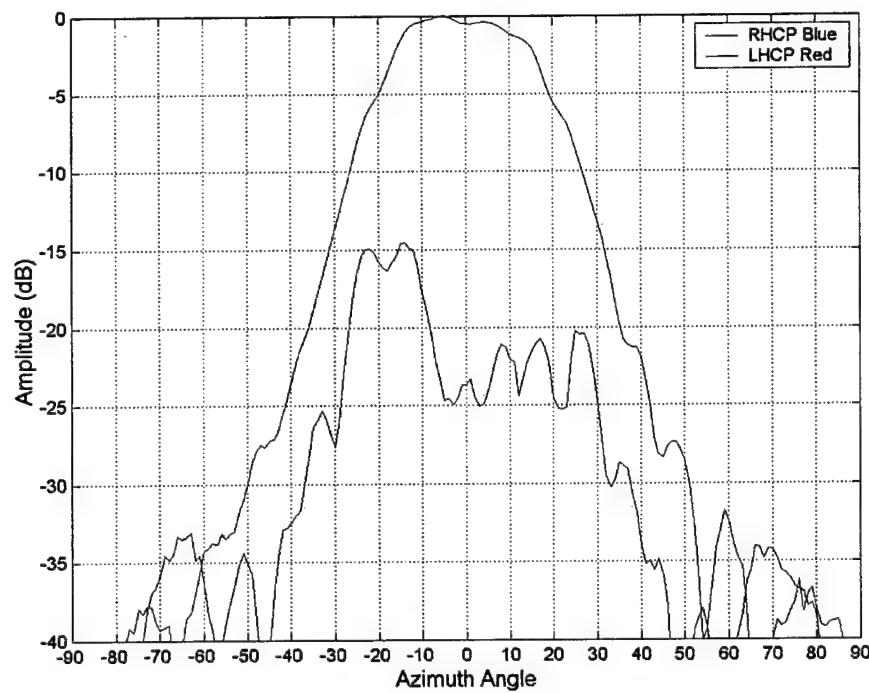


Figure 8. 29.25 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern



*Figure 9. 29.5 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern*



*Figure 10. 29.75 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern*

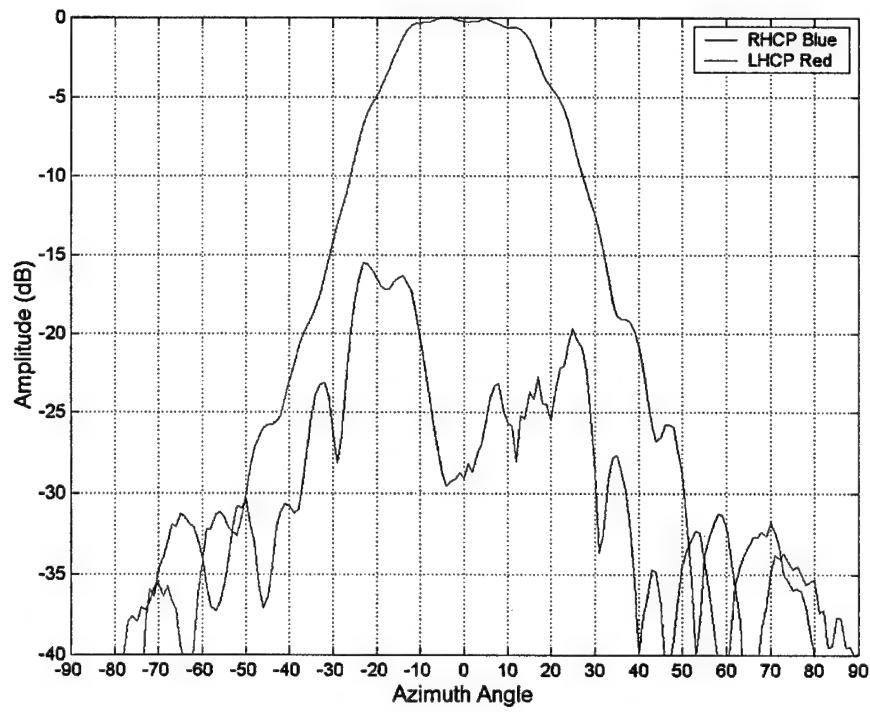


Figure 11. 30.0 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern

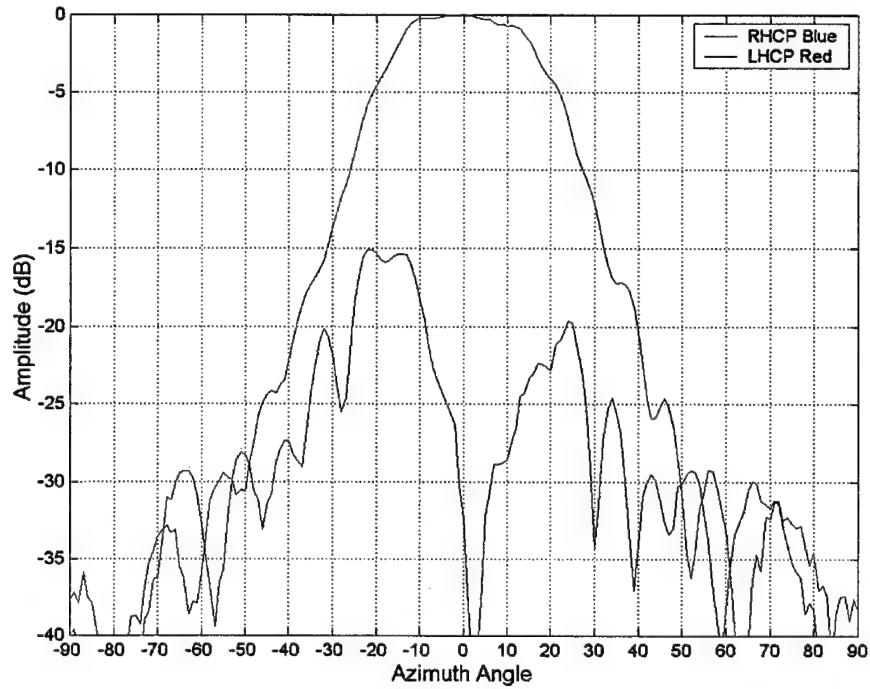


Figure 12. 30.25 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern

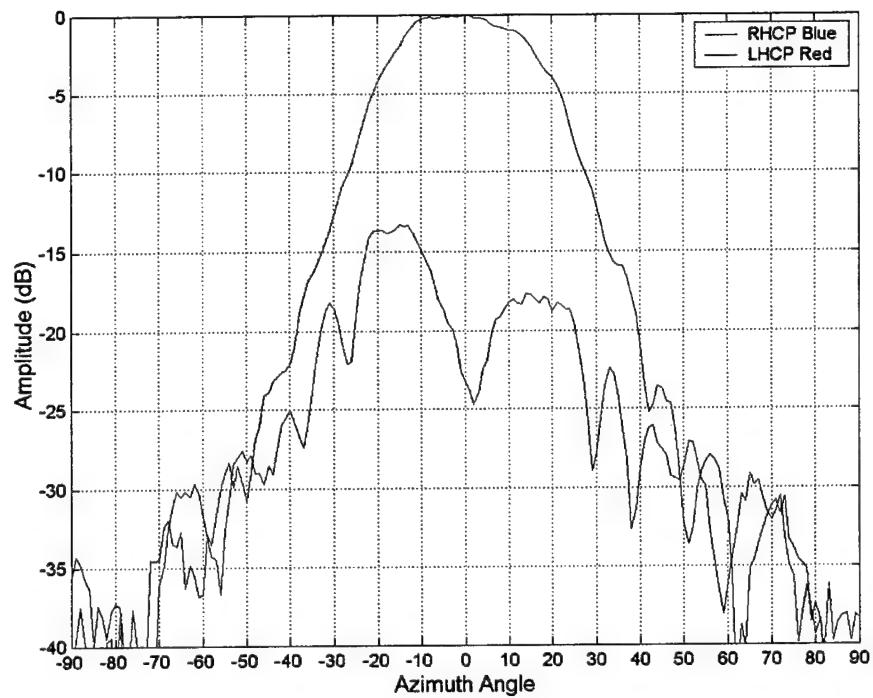


Figure 13. 30.5 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern

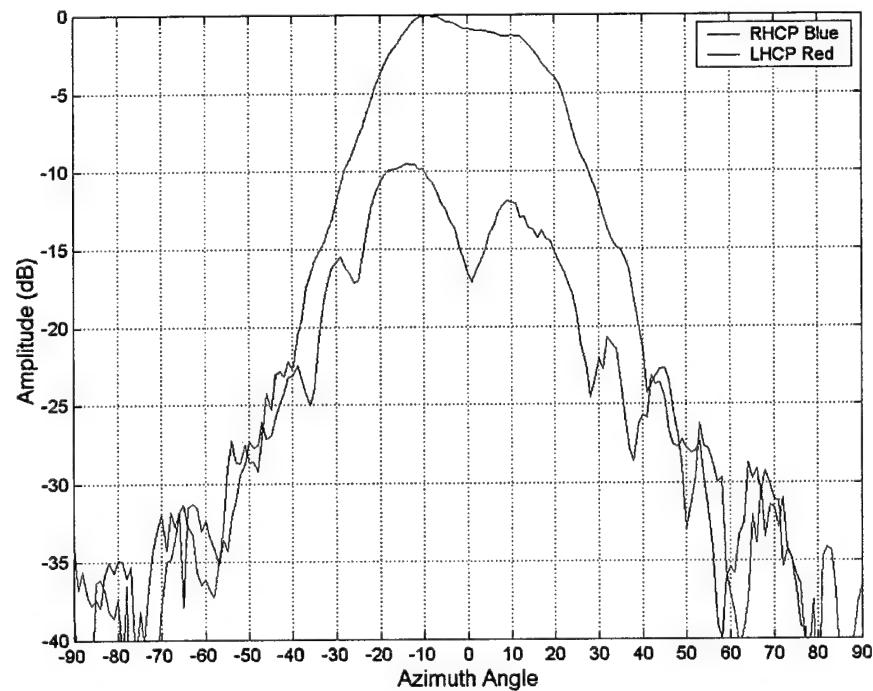


Figure 14. 30.75 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern

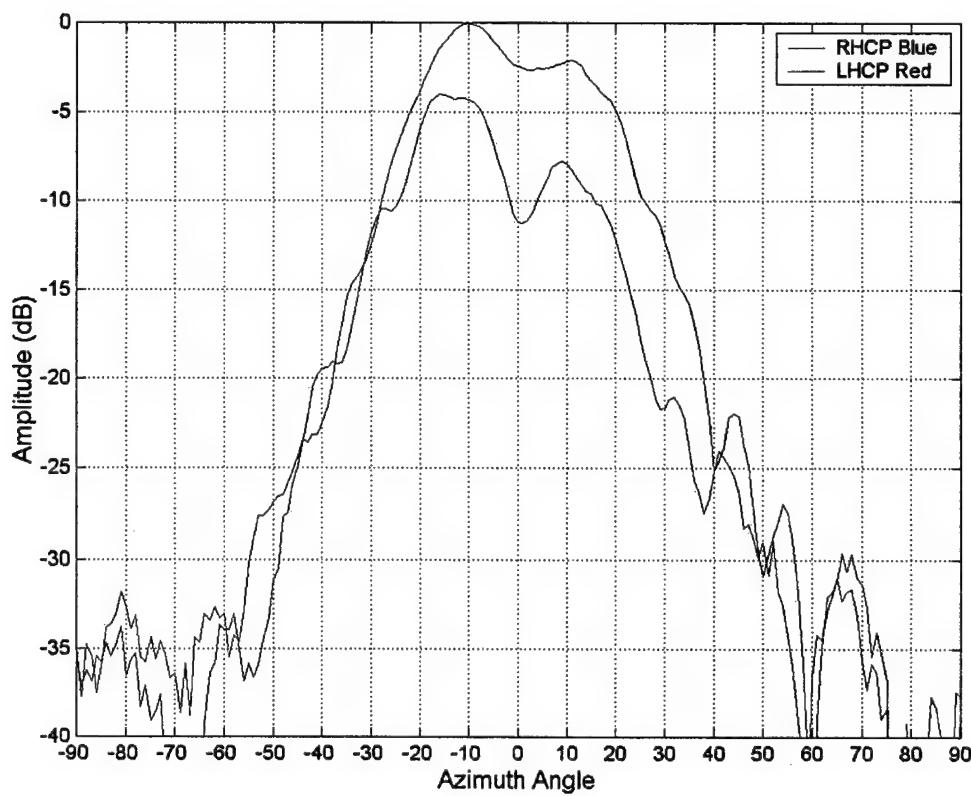


Figure 15. 31.0 GHz Co-Polar (RHCP) and Cross-Polar (LHCP) Azimuth Radiation Pattern

**Table 2. K-Band Tabular Data**

| Freq(GHz) | Axial Ratio(dB) | Gain(dBi)        | Return Loss (dB) | VSWR |
|-----------|-----------------|------------------|------------------|------|
| 20.20     | 0.70            | 15.66            | -25.05           | 1.12 |
| 20.25     | 0.45            | 15.72            | -16.79           | 1.34 |
| 20.30     | 0.90            | 15.57            | -17.56           | 1.31 |
| 20.35     | 0.60            | 15.49            | -25.89           | 1.11 |
| 20.40     | 0.70            | 15.51            | -26.21           | 1.10 |
| 20.45     | 0.90            | 15.49            | -21.67           | 1.18 |
| 20.50     | 0.95            | 15.51            | -25.33           | 1.11 |
| 20.55     | 0.50            | 15.45            | -23.29           | 1.15 |
| 20.60     | 0.75            | 15.54            | -19.89           | 1.23 |
| 20.65     | 1.05            | 15.69            | -23.38           | 1.15 |
| 20.70     | 1.03            | 15.45            | -28.99           | 1.07 |
| 20.75     | 1.00            | 15.47            | -21.01           | 1.20 |
| 20.80     | 1.17            | 15.67            | -21.75           | 1.18 |
| 20.85     | 1.10            | 15.53            | -26.13           | 1.10 |
| 20.90     | 1.25            | 15.54            | -19.14           | 1.25 |
| 20.95     | 1.00            | 15.54            | -16.60           | 1.35 |
| 21.00     | 1.37            | 15.48            | -18.47           | 1.27 |
| 21.05     | 1.40            | 15.46            | -25.64           | 1.11 |
| 21.10     | 1.25            | 15.24            | -20.45           | 1.21 |
| 21.15     | 1.45            | 15.20            | -18.96           | 1.25 |
| 21.20     | 1.68            | 15.18            | -19.37           | 1.24 |
| Freq(GHz) | BeamWidth(3dB)° | BeamWidth(10dB)° | x-pol(dB)        |      |
| 20.20     | 30.53           | 53.13            | -19.88           |      |
| 20.45     | 30.87           | 53.48            | -17.80           |      |
| 20.70     | 31.20           | 53.10            | -17.03           |      |
| 20.95     | 31.71           | 52.78            | -17.24           |      |
| 21.20     | 32.83           | 53.32            | -15.06           |      |

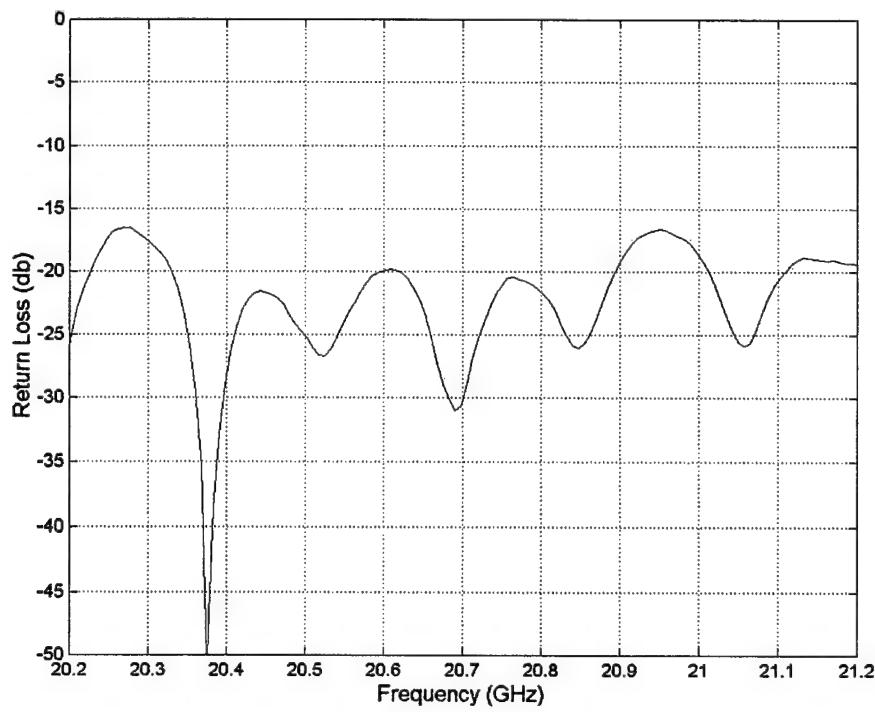


Figure 16. K-Band Return Loss Graph

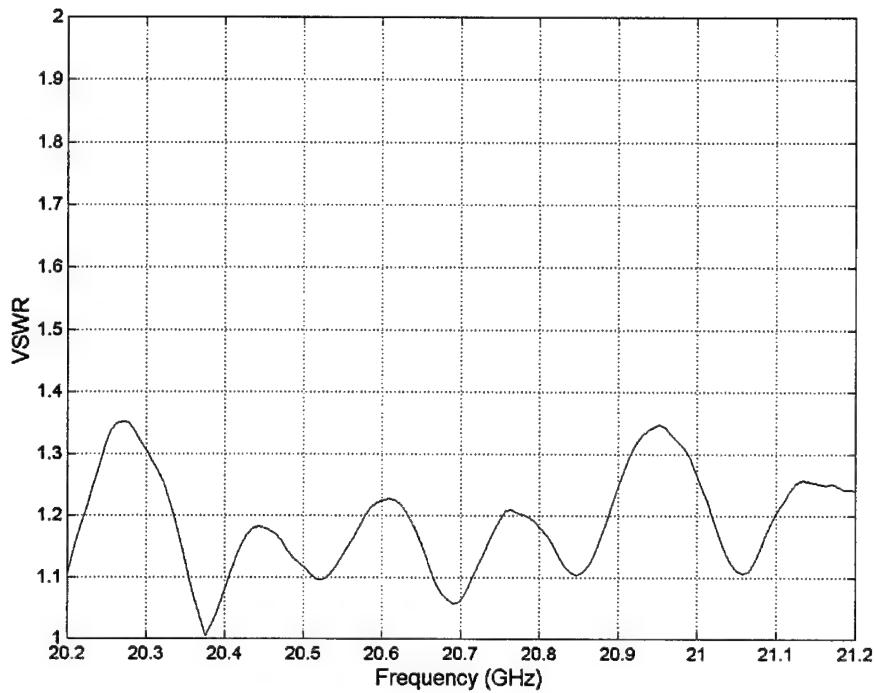


Figure 17. K-Band VSWR Graph

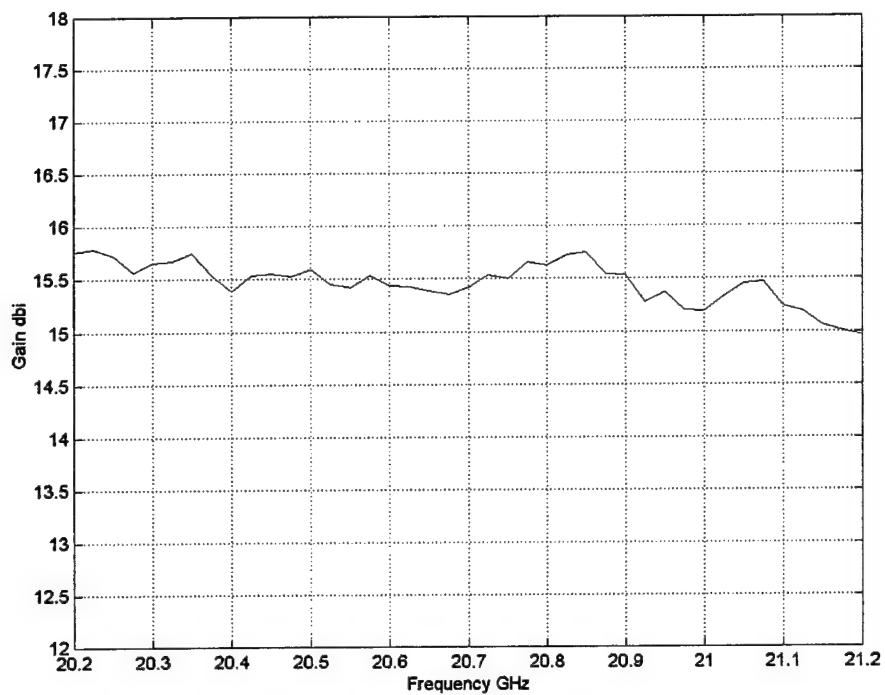


Figure 18. K-Band LHCP Swept Frequency Gain Graph

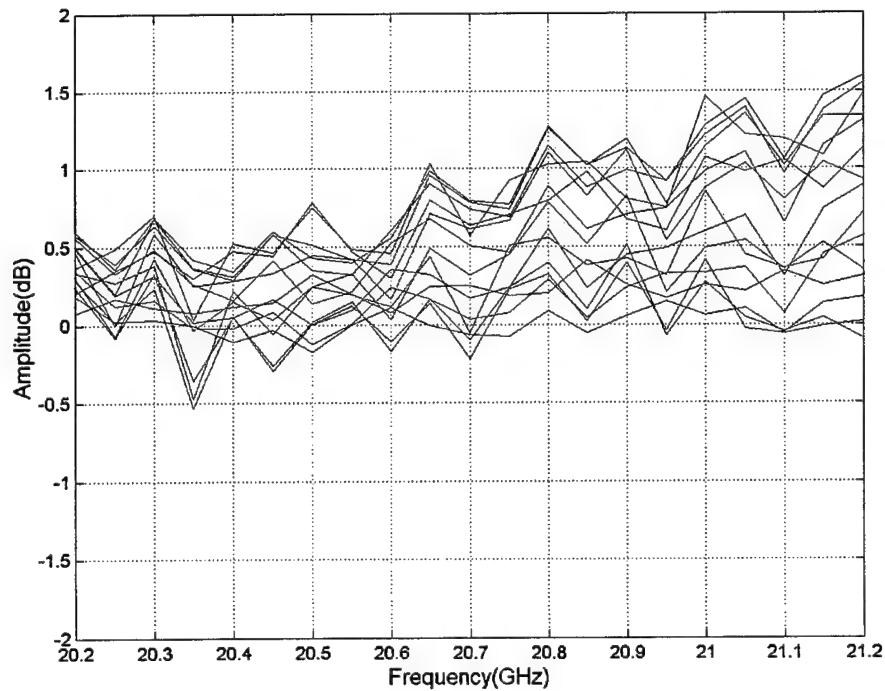


Figure 19. K-Band Axial Ratio Graph

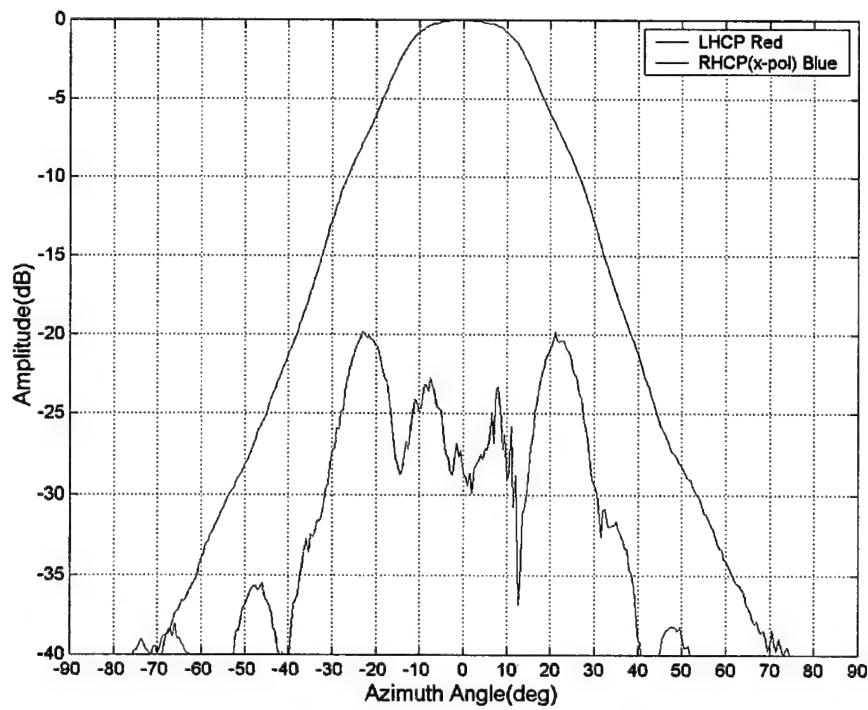


Figure 20. 20.2 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) Azimuth Radiation Patterns

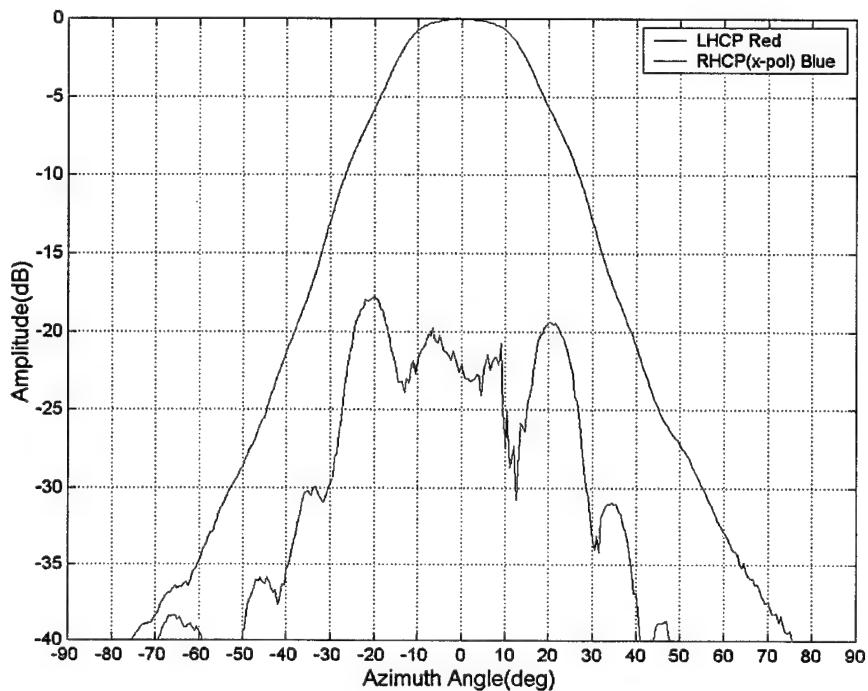


Figure 21. 20.45 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) Azimuth Radiation Patterns

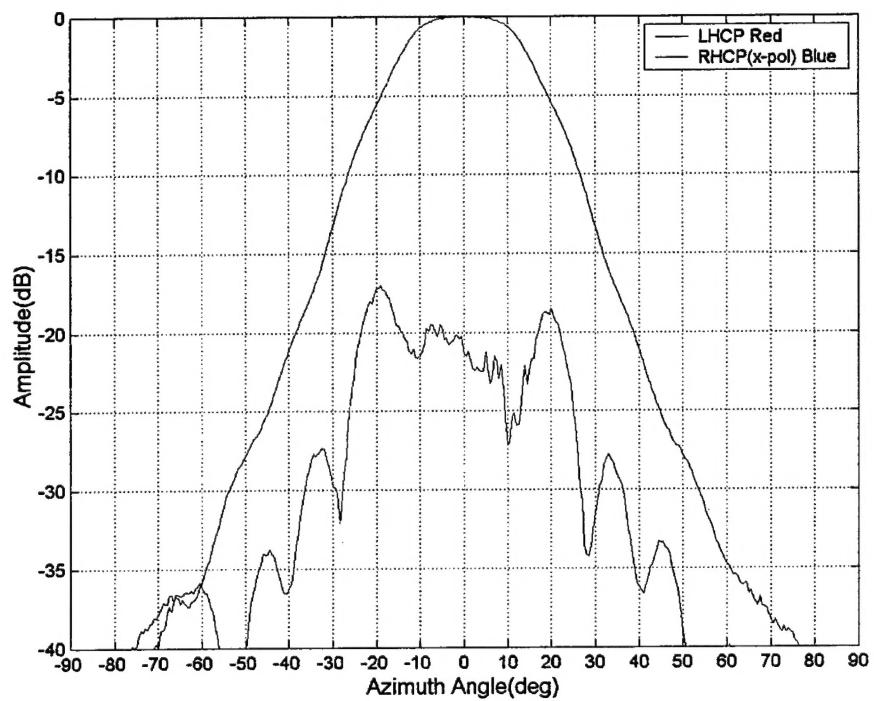


Figure 22. 20.7 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) Azimuth Radiation Patterns

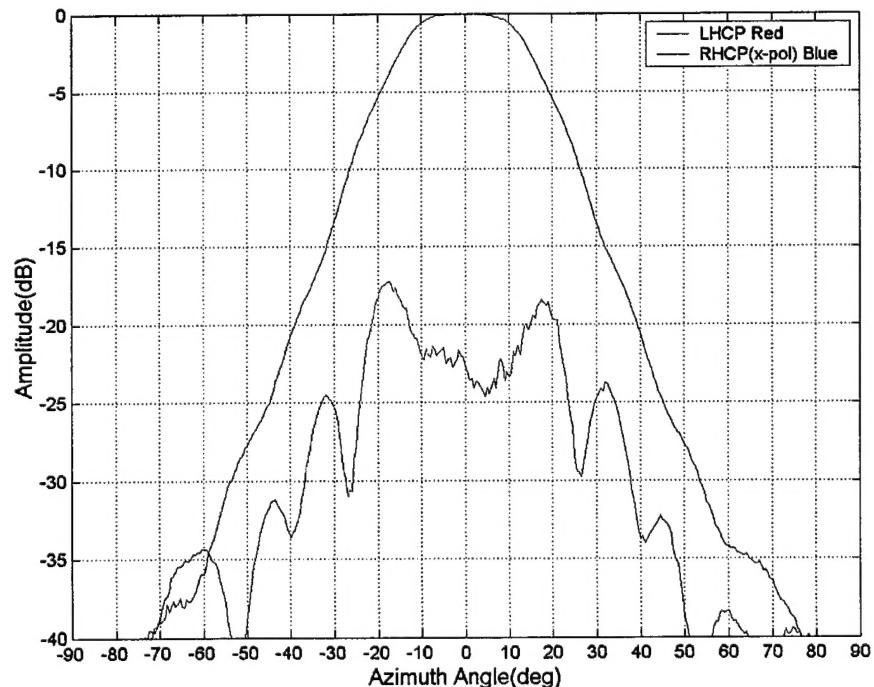


Figure 23. 20.95 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) Azimuth Radiation Patterns

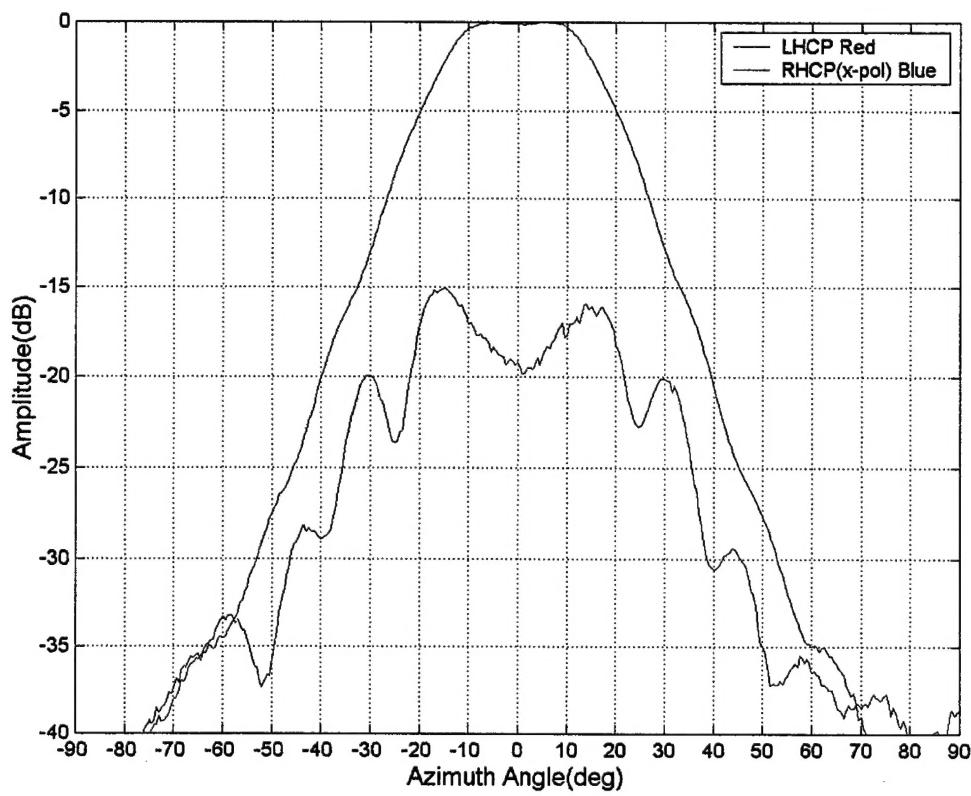


Figure 24. 21.2 GHz Co-Polar (LHCP) and Cross-Polar (RHCP) Azimuth Radiation Patterns

#### **4.0 CONCLUSION**

Measurements have shown the Ka-band Terminal feed to exhibit reasonable performance over a 1 GHz bandwidth at K-Band. Within the K-band 1 GHz bandwidth (20.2–21.2 GHz), an axial ratio <1.68 db, nominal gain of 15.5 dbi, return loss <16.6 db, and a maximum cross polarization level of 15 db is achieved. At Ka-band, a 1 GHz bandwidth from 30–31 GHz shows that the feed has seriously degraded performance above 30.6 GHz, with 3 db less gain at 31 GHz than at 30.5 GHz and an axial ratio of 6.5 db at 31 GHz. The radiation patterns also demonstrate deterioration from 30.75 to 31 GHz. However, since good performance can be achieved from 29.6–30.6 GHz, it may be possible to retune the feed. Thus major modification and retuning of the feed will be necessary to achieve good performance in the Ka-band uplink (30-31 GHz) band for the Wideband Gapfiller System.

# REPORT DOCUMENTATION PAGE

*Form Approved  
OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

|  |   |  |   |
|--|---|--|---|
| 1. AGENCY USE ONLY ( <i>Leave blank</i> )  | 2. REPORT DATE  | 3. REPORT TYPE AND DATES COVERED                           |   |
|  | 23 May 2001   | Technical Report   |   |
| 4. TITLE AND SUBTITLE<br><br>GBS IOTE Feed Measurements  |   |  | 5. FUNDING NUMBERS<br><br>C—F19628-00-C-0002                          |
| 6. AUTHOR(S)<br><br>T.W. Borge   |   |  |   |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><br>Lincoln Laboratory, MIT<br>244 Wood Street<br>Lexington, MA 02420-9108   |   |  | 8. PERFORMING ORGANIZATION REPORT NUMBER<br><br>TR-1073               |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br><br>AFSMC/MCW<br>2420 Vela Way, Suite 1467-A8<br>El Segundo, CA 90245   |   |  | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br><br>ESC-TR-2000-056 |
| 11. SUPPLEMENTARY NOTES<br><br>None  |   |  |   |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT<br><br>Approved for public release; distribution is unlimited.  |   | 12b. DISTRIBUTION CODE                                     |   |
| 13. ABSTRACT ( <i>Maximum 200 words</i> )<br><br>The KaBand (30/20 GHz) terminal was used to conduct I, O, T, and E of the Global Broadcast System (GBS) package on UHF Follow-on (UFO) satellites, flights 8, 9, and 10. This terminal has been transferred to Lincoln Laboratory through the Milsatcom Joint Program Office at the USAF Space and Missile Center (AFSMC). At Lincoln Laboratory, the terminal is to be evaluated for possible use in on-orbit checkout/experimentation with the Ka-band portion of the Wideband Gap Filler Satellites (expected to launch in 2004). These satellites use the government 20.2-21.2 GHz (downlink) and 30-31 GHz (uplink) frequency allocations. This report describes the test and evaluation of the Ka-Band Terminal dual frequency feed at Lincoln Laboratory's Antenna Test Range and identifies some deficiencies that will need to be addressed prior to use with the Wideband Gapfiller system. |   |  |   |
| 14. SUBJECT TERMS  |   |  | 15. NUMBER OF PAGES<br>28   |
|  |   |  | 16. PRICE CODE  |
| 17. SECURITY CLASSIFICATION<br>OF REPORT<br>Unclassified   | 18. SECURITY CLASSIFICATION<br>OF THIS PAGE<br>Unclassified | 19. SECURITY CLASSIFICATION<br>OF ABSTRACT<br>Unclassified | 20. LIMITATION OF<br>ABSTRACT<br>Same as Report                       |